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Edited for the Council by J. LAURENCE PRITCHARD, Fellow.

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Notices of the Royal Aëronautical Society.

Silver Medal.

At a Council Meeting held on July 18th it was decided to award the Society's Silver Medal for 1921 to Mr. H. Ricardo for his paper entitled "Some Possible Lines of Development in Aircraft Engines." The Silver Medal will in future be awarded annually to the author of the paper which is, in the opinion of the Council, the best of those published in the AERONAUTICAL JOURNAL each year.

Finance.

A statement of accounts for the six months ending June 30th, 1922, has been prepared in the office and presented to the Council. It is regretted that this discloses an excess of expenditure over income of £75 19s. 4d. It is hoped, however, that the remainder of the year will produce a sufficiently satisfactory result to leave only a small deficit on the whole year's working.

Journal.

It is gratifying to find that the number of subscriptions to the JOURNAL from persons outside the membership of the Society has recently been increasing considerably. Technical members of the Society can materially assist in this direction by forwarding contributions embodying the results of their work to the Editor.

Usborne Memorial Fund.

It is regretted that the subscription of 25 guineas towards this Fund from Sir Trevor Dawson was inadvertently credited to the Pilcher Memorial Prize for Students. This increases the total of the Usborne Fund to £99 14s. 0d., and involves a corresponding decrease in the Pilcher Prize to a total of £111 0s. 0d.

Examination.

The first Associate Fellowship examination, in accordance with the new regulations, will be held on Monday, September 25th (Part I.), and Tuesday,

September 26th (Part II.), in the Library at 7, Albemarle Street, London, W.1. Entries, accompanied by the prescribed examination fee, should reach the Secretary not later than Monday, August 28th.

Office Closing.

Members are reminded that the Offices and Library will be closed for annual cleaning until August 15th.

W. LOCKWOOD MARSH, *Secretary.*

PROCEEDINGS.

TWELFTH MEETING, 57th SESSION.

A meeting of the Society was held in the rooms of the Royal Society of Arts, Adelphi, London, on Thursday, April 6th, 1922, the Chairman (Lieut.-Colonel M. O'Gorman) in the chair.

The CHAIRMAN said that the members were to hear M. Louis Breguet, whose name they were too well acquainted with to need any introduction from him. The members ought to know, however, that M. Breguet had been decorated in 1911 and subsequently promoted to the rank of officer of the Legion of Honour, in France, for the services he had rendered during the war, and moreover, that he was the President of what corresponded, in France, to the Society of British Aircraft Constructors, namely, the Chambre Syndicale des Industries Aéronautiques. (Applause.)

The CHAIRMAN then called upon M. Breguet to read his paper on "Aerodynamical Efficiency and the Reduction of Air Transport Costs."

AERODYNAMICAL EFFICIENCY AND THE REDUCTION OF AIR TRANSPORT COSTS.

The possibility for aeroplanes used in air transport services to be made to pay has, so far, been very often questioned, considering the present cost price per ton-mile flown.

I intend to demonstrate that one can, from now, predict an important reduction in air freight rates, not only through greater safety of flight mainly resulting from a longer life of aeroplanes and engines, but also through the betterment of several coefficients which characterise the aerodynamical qualities of aeroplanes.

The study of these coefficients can be made either by laboratory tests on models or by full-scale tests in flight which, if judiciously interpreted, should yield information sufficiently accurate for practical purposes.

May I remind you that the principles of aerodynamics lie in the following formulæ :—

$$R_x = (K_x + \sigma/S)\, S V^2 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

wherein :—

R_x is the total drag of the whole aeroplane along the direction of motion.
K_x is a coefficient relating to R_x and dependent upon the value of the angle of incidence in flight.
σ is the projected area, normally to the direction of motion, representing the passive resistances of the aeroplane.
S is the projected area of the wings on a plane parallel to the direction of motion.
V is the speed of the aeroplane along the trajectory.

$$R_y = K_y S V^2 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

wherein :—

R_y is the lift of the aeroplane, normal to the direction of motion.
K_y is a coefficient relating to R_y and dependent upon the value of the angle of incidence in flight.

Dividing equation No. (1) by equation No. (2), which gives the ratio of drag to lift, we have:—

$$R_x/R_y = (K_x + \sigma/S)/K_y = \tan\phi \quad . \quad . \quad . \quad . \quad (3)$$

That expression $\tan\phi$ is usually called the "fineness" of the aeroplane, and every aeroplane is characterised by a certain minimum value of $\tan\phi$ which can be represented by $\tan\phi_m$. The smaller $\tan\phi_m$ is the better will be the aerodynamical qualities of the aeroplane.

That fineness is used when calculating the longest distance which a given aeroplane can fly in a "no wind" atmosphere.

$$L = (622\,\rho/m\tan\phi_m)\log P/(P - p) \quad . \quad . \quad . \quad (4)$$

wherein:—

L is the said longest distance in kilometres.
ρ is the efficiency of the propeller.
m is the "fuel and oil" consumption of the engine per horse-power and per hour in kilogs.
P is the total weight in kilogs. of the aeroplane and cargoes at the start.
p is the weight in kilogs. of the "fuel and oil" consumed by the engine during the flight and which was included in P.

One at once realises the very great importance of the fineness $\tan\phi_m$ which in that formula is the only term depending upon the aerodynamical qualities of the aeroplane.

For certain given values of L, ρ, m and P, a reduction of $\tan\phi_m$ causes a reduction in the "fuel and oil" consumption, and consequently increases the weight of paying freight which could be carried.

The conclusion is that one must bring to the minimum the value of $\tan\phi_m$. It can be obtained by choosing the best possible profile for the wings, the best designs for the body, empennage, etc. Moreover, the undercarriage should be made to disappear inside the body or the wings when the aeroplane is in flight, etc.

Another interesting coefficient appears when one calculates the power spent in horizontal flight is given by the formula:—

$$W = R_x V = (K_x + \sigma/S)\,SV^3 \quad . \quad . \quad . \quad . \quad (5)$$

where

W is the power in kilogrammetres.
R_x is the drag in kilogs. as calculated by formula (1).
S is the wing area in square metres.
V is the speed in metres per second.

On another side, the value of the lift, as given by formula (2), is equal to the total weight P of the aeroplane in horizontal flight. We thus have:—

$$P = R_y = K_y S V^2 \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Eliminating the speed V between the two equations (5) and (6) we come to another formula giving the power W:—

$$W = P\sqrt{(P/S)}\,(K_x + \sigma/S)/(K_y)^{3/2} \quad . \quad . \quad . \quad (7)$$

We thus see that the necessary power is in direct proportion to the value of the term

$$(K_x + \sigma/S)/(K_y)^{3/2}$$

I have represented the term by the Greek letter ζ and call it the *coefficient of power*.

For a given aeroplane, the value of ζ will reach a minimum for a certain angle of incidence in flight, and to that particular value of ζ will correspond the minimum of power required, and that is why I propose to call that special value ζ_m the *coefficient of minimum power*.

That coefficient of minimum power is used to calculate the minimum power necessary to maintain in horizontal flight a given aeroplane, and the height of ceiling chosen will fix the nominal power to be provided for the engine. One can therefore see that, should it be possible to reduce in the proportion of two to one, for instance, the value of ζ_m, then an engine of half the nominal power would be sufficient to reach the same ceiling.

Since I have now clearly shown the way these several coefficients affect the aerodynamical qualities of aeroplanes, I can explain to you how one can design in the future, starting from existing aeroplanes, new ones which should reduce by more than one half the present rates of aerial freight, and how also, when bringing other improvements which I will specify later on, one can expect to bring down the rates of aerial freight to the value of those now charged in France for first class railway passengers.

An aeroplane of high standard quality now has:—

A fineness equal to	0.12
Its coefficient of minimum power is equal to	0.55
Its propeller efficiency is	0.73
Fuel and oil consumption of its engine at an altitude of 2,000 metres is 290 grammes per horse-power and per hour.	

We will, moreover, admit the total weight of that aeroplane to be such as to allow it to climb to 4,500 metres within one and a half hours if the engines are run at full power,* and we will consider an aerial line of 800 kilometres non-stop flights.

If such an aeroplane has a wing surface of 100 square metres, for instance, and a power plant of 600 horse-power, its dead weight will be equal to 2,200 kilogs., and it will be able to carry a total load of 2,100 kilogs. Its total weight will thus be equal to 4,300 kilogs.

Its flying speed at full power at an altitude of 2,000 metres will reach 175 kilometres an hour, and its commercial speed at the same altitude can be reckoned as to be equal to 150 or 155 kilometres an hour.

The weight of fuel and oil necessary in a still atmosphere for a given flight is deduced from the formula (4), which, in the present case, gives the weight as being 568 kilogs.

But practical flying has proved that one must expect to have to fly against a fifty kilometres an hour wind, and therefore it is necessary to have at least a fifty per cent. safety margin in fuel and oil. In other words, we shall have to carry in the case under consideration a total weight of fuel and oil equal to $568 \times 1.5 = 850$ kilogs., whilst the average consumption will only be of about 1.1 times the calculated quantity of 568 kilogs., that is to say, 625 kilogs.†

The crew (pilot and second pilot-mechanic) together represent a weight of about 180 kilogs., and another 70 kilogs. are necessary for various instruments and T.S.F. apparata.

The total weight of fuel and oil, crew and instruments thus reaches eleven hundred kilogs., leaving a clear margin of one thousand kilogs. for passengers and paying cargo.

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* It means that the nominal power of the engines, multiplied by the propeller efficiency, must be equal to about two to three times the minimum power necessary for horizontal flying at sea level.

† The coefficient 1.1 is the average of data registered on several hundred flights.

The present running costs of an aerial line of 800 kilometres long, with the above aeroplanes, are as follows:—

	Francs.
Petrol (820 litres at francs 1.82 for 800 kilom. flown) per kilom.	1.87
Oil (50 litres at francs 3 for 800 kilom. flown)	0.19
Crew (pilot at francs 0.20 per kilom., second pilot-mechanic at francs 0.15)*	0.35
Sinking fund for aeroplane and engine	6.50
Upkeep of aeroplane and engine and aeroport expenses, etc. ...	4.50
General expenses of the company	4.00
Francs	17.41

Should an aeroplane always fly with full cargo load and without incident or interruption, the cost price per ton and per kilometre would thus be about 17.40 francs. But one has to reckon with trips made with smaller paying loads, or incidentally interrupted, and therefore it is wise to calculate the cost price per ton on flights with half cargo loads as an average, which brings the present cost price per ton and per kilometre to 35 francs. That is about the price at which are now working the best aerial lines. A few companies work on still higher prices, either because the average cargo load is less than one half the maximum, or because they fly over particularly awkward grounds. They then reach such prices as 50 francs or £1 12s. 0d. per ton-mile.

Should such prices be considered as irreducible they would be practically prohibitive and little chance would be left to commercial aviation, since one would have to charge from eleven to twelve hundred francs per passenger from Paris to London or vice versa, without any profit to the company.

How can these figures be reduced in the near future? We will consider:—

1.—Advantages to be drawn solely from the betterment of aerodynamical qualities of the aeroplanes and of the thermal efficiency of engines.

2.—Advantages resulting from such improvements in the engines and in mechanical parts of aeroplanes as would bring reductions in the provision for sinking funds, upkeep of machines and general expenses.

1.—Advantages to be drawn solely from the betterment of aerodynamical qualities of the aeroplanes and of the thermal efficiency of engines.

Taking, for the sake of demonstration, the same size of aeroplane as already considered, that is to say:—

Wing area: 100 square metres.
Total weight: 4,300 kilogs. at the start.
Ceiling: 4,500 metres.

And if we suppose that we can bring down:—

Its fineness to	0.065	instead of	0.12
Its coefficient of minimum power to ...	0.28	,,	0.55
Its propeller efficiency to	0.775	,,	0.73
The fuel and oil consumption of its engines per horse-power and per hour to	215	,,	290 grams

* Several companies now have to spend an average of 0.50 francs per kilometre for the crew, but that is because their lines are rather short ones (say, 375 kilometres on Paris-London), and also that the crew only flies one single trip a day, and not every day. With the present minimum of salary one has to guarantee them, as also with the number of pilots one has to keep according to subsidies-regulations, these pilots are far from rendering efficient work (from "distances flown" point of view). The figures I have taken of 0.35 francs apply to lines of some 800 kilometres, a few of which are now in contemplation.

then such an aeroplane will not require more than 288 horse-power to reach the same ceiling of 4,500 metres instead of 600 h.p.

It is evident that the reduction in power is only due to the betterment of the coefficient of minimum power and of the efficiency of the propeller.

One can thus spare 312 horse-power, which means a saving of 468 kilogs. of dead weight (at the rate of one and a half kilogs. per horse-power for the engine and its appliances).

The quantity of fuel and oil to be carried can be deduced from the formula (4), as has already been done for the first type of aeroplane considered. This gives

$$p = 230 \text{ kilogs.}$$

The weight it is wise to carry up will be taken equal to

$$230 \times 1.5 = 345 \text{ kilogs.}$$

and the average actual consumption will be about

$$230 \times 1.1 = 255 \text{ kilogs.}$$

The weight saved on fuel and oil with the second type of aeroplane will thus be practically

$$850 - 345 = 505 \text{ kilogs.}$$

and the excess of useful load is thus increased to a total of

$$468 + 505 = 973 \text{ kilogs.}$$

The commercial efficiency of that type of aeroplane will thus be practically double that of the first type, since it will be able to carry 1,973 kilogs. of passengers or paying freight, instead of 1,000 kilogs.†

At the same time that aeroplane will cost about 25 per cent. less than the first, since its nominal power plant will only be half the size of the first, and the value of the nominal power plant now represents about half the price of an aeroplane.

The running cost of the new type of machine will then be as follows:—

	Francs.
Petrol (335 litres at francs 1.82 for 800 kilometres) per kilom.	0.765
Oil (20 litres at francs 3 for 800 kilometres)	0.075
Crew	0.35
Sinking fund (75 per cent. of francs 6.50, since the cost price of the aeroplane has been found reduced in that proportion)	4.90
Upkeep of aeroplane and engine and aeroport expenses ...	4.50
General expenses of the company	4.00
Francs	14.59

As the paying load has been raised to 1,973 kilogs., the cost price per ton and per kilometre becomes equal to 7.40 francs, or—if calculated on a half cargo load basis—14.80 francs instead of the present cost price of 35 francs. London to Paris passenger fares can then be brought down to some 450 or 500 francs without profit for the company. Although very high, these last figures are more encouraging and nearly workable.

† As a matter of fact, one should deduce from that weight some 180 to 200 kilogrammes for the accommodation of the surplus of passengers and freight. But on another side one can reasonably expect that the daily progress made in the manufacture of aeroplanes and the use of stronger material will allow saving on dead weight of practically the same amount.

2.—Advantages resulting from such improvements in the engines and in mechanical parts of aeroplanes as could bring reduction in the provisions for sinking funds, upkeeping and general expenses.

When one can rely on an average life of one thousand hours for aeroplanes and engines instead of the present 200 or 250, much better prices will be obtained. Supposing that such an aeroplane be bought for the same price as the last one mentioned, but calculating on 1,000 hours life, the sinking fund only calls for 1.10 francs, whilst the upkeep can be reasonably considered as half as expensive since the aeroplanes and engines will be of much better quality and strength. General expenses will also be considerably reduced through the much larger turnover that the companies will then be able to secure.

In such conditions the running costs would be as follows:—

Petrol	per kilometre, francs	0.765
Oil		0.075
Crew		0.35
Sinking fund		1.10
Upkeep		2.25
General expenses (estimated)		1.00
	Francs	5.54

That is to say, 5.55 francs for 1,973 kilogs. carried, or 2.82 francs per ton and per kilometre, or 5.65 francs if calculated on the usual half cargo load basis. Then the Paris to London fare will become about 190 francs, or say £4, the present price of the third class railway fare.

When that time comes then the aerial transport companies will be flourishing paying concerns, and no more subsidies will be required from the State, because the time saved in travelling by air from Paris to London, for instance, will certainly be worth a fare of say £6, showing £2 profit on each passenger.

It is worth noting in the last cost price we have given that fuel and oil, although intrinsically very expensive, amount to only fifteen per cent. of the total cost price, whilst the crew draws 6.4 per cent.

On the other side, sinking fund, upkeep and general expenses, which, on the present cost of 35 francs, represent 86 per cent. of the total cost price, have grown to 92 per cent. with the second example and come down to 78 per cent. in the last considered circumstances.

May I therefore state—in opposition to the sayings and writings of certain experts who do not know much about aerial transports—that it is not the cost of fuel or crew which makes aeroplanes expensive machines, but only their present short life, with resulting consequences. But we must expect and hope to see large and strong aeroplanes of the future become as safe as motor cars, steamships and railways, and when that time comes, then we will be able to apply to sinking funds the same coefficient as is now used for steamships, that is to say, about an average life of twenty-five years!

From the example I have taken for the purpose of demonstration of an aeroplane of one hundred square metres wing area and 4,300 kilogs. total weight, you must not infer that I expect the improvements of aerodynamical qualities (with the consequences I drew from it) to be realised by such small machines. I believe one can build very good aeroplanes of four to five tons total weight; but I think it would be much nearer to reality to talk of 500 square metres wing surface, twenty to forty tons total weight and fifteen hundred to four thousand horse-power. Such large machines* will most probably have very thick wings.

* Which being probably much more heavily loaded per square metre will be able to reach speeds of about 150 m.p.h.

By thick, I mean about six feet, and within these wings will be provided cabins, saloons and every comfort for passengers. It is worth noting that if a large increase of the size of an aeroplane does not improve materially its commercial efficiency, it has nevertheless the great advantage of allowing much more room for passengers and freight, and that can be easily understood when one remembers that whilst the weight, the power, the capacity in cargo and the cost price of an aeroplane vary as the square of its lineal dimensions, the volume to be reserved for passengers will vary as the cube of the same dimensions. In other words, if the weight, surface and power have been increased one hundred times, then the cubic capacity will be one thousand times larger.* Passengers, for instance, will proportionately dispose of ten cubic metres each instead of one cubic metre in the first case, and that shows one of the most important advantages to be drawn from the manufacture of very large machines.

It is not exaggeration to talk of the days when the price of aerial transport will come down to two francs per ton and per kilometre, since an average life of two or three years—or say two thousand hours of flight—for aeroplanes and engines would suffice to bring that result, even with petrol and oil at their present very high prices. It is practically certain that aeroplanes of the future will not burn petrol but rather heavy oils or other cheap fuels, the cost price of which should be about one-fifth that of petrol.

Now first class passenger fares in France are calculated on the basis of 21.15 francs per one hundred kilometres. Supposing that a passenger with his hand luggage weighs an average of ninety kilogs., we find that the ton-kilometre (passenger) runs to 2.35 francs. That shows that the future prices of aerial transports will be of the same order as the present first class passenger fares in France.

More striking still is the comparison with the fares on steamship lines, since a first class passenger nowadays pays about six francs per ton-kilometre, whilst state cabins are charged at the rate of ten francs.

In conclusion, aerial transports are very expensive for the present because they are not yet out of the experimental stage and that the sinking funds, the upkeep and general expenses are very heavy; but one can reasonably say that within ten years these costs should be reduced in the proportion of seven to one, and within twenty years roughly in the proportion of fifteen to one.

Moreover, one must not forget that "time is money," and therefore a saving of four or five days on London to Cairo, for instance, will be of tremendous value to business men. The fares charged will then be of comparatively small importance to them as long as safety and speed are secured, and as aeroplanes will be unbeatable as regards speed, aerial transports are bound to wipe out all other systems of international communications.

We must therefore work hard and steadily, with full confidence in the future of aviation.

DISCUSSION.

The CHAIRMAN said they had listened with interest to M. Breguet's display of an optimism which was well worthy of their respect. He had indicated the steps by which they might compete on equal terms with railways for certain classes of traffic, and if they did not arrive at the whole result they might look step by step at the various factors and see which of them they had failed to bring up to the high level which had been foreseen. He had suggested that the fineness of aircraft could be improved by 50 per cent. He had shown the hope that fuel consumption might be reduced, and had discussed similar factors, showing that

* If the aeroplanes have been built from the same drawings read on a larger scale.

even if these factors of improvement could not all be obtained *in toto*, he had shown that the sum of the advances obtainable make a fundamental and logical improvement in the whole aeronautical situation. M. Breguet's optimism was legitimate if the moneys spent on research were not reduced. Each specialist could then tackle, in his own sphere, some one of the problems that M. Breguet had exposed, and in such measure as they secured improvement, these would become operative together, and we should approach the competition, on an equal basis of charge, of first class railway fare and travel by aeroplane, with the enormous advantage to the aeroplane traveller that he had saved so much in time. With regard to the author's prophecy of the 40-ton monoplane, he did not suppose that an engineer of the author's distinction would have put that forward entirely at random without having thought it out as a thing thoroughly worth considering as a commercial possibility. The author had shown that the real incoming of aerial transport was not going to be achieved by prophetic letters to the Press nor yet by meetings of the Civil Aviation Advisory Board at the Air Ministry, unless the latter proved themselves competent to understand the technical nature of the problem and secured a sufficient addition of funds for the specialised research which civil transport needed. He agreed that civil transport was the basis for full factories and full factories the basis of military aeronautical operations. Nothing else but the scientific work of men of intelligence and intellect in the laboratory and in the air would solve the technical problems; and nothing but a solution of the scientific problems could make air transport self-supporting. Everyone would agree that that was the solution to be obtained. It was deplorable to realise that the authorities seemed so little capable of realising this, that they allowed the technical and research expenditure to be cut down with a view to national economy; he felt very strongly that this was simply national extravagance. It was killing that which alone could economically keep the aircraft factories in being in the state necessary to provide the fighting machines for aerial defence—Britain's, and indeed any country's, first line of defence.

Mr. F. HANDLEY PAGE said it was very interesting to have M. Breguet to address a meeting of the Royal Aëronautical Society. He had been one of the great pioneers of aviation, and one who had devoted himself not merely to the type of aircraft that they saw flying to-day, but he believed some of his earliest efforts were in the direction of the helicopter, which, if it had not produced practical results, had at least produced a very lengthy correspondence from the inventors. In having M. Breguet at the meeting the Society was greatly honoured. He (the speaker) was an optimist; his optimism was not based merely on the feeling that the success of air transport depended solely on the research laboratory, which the President had emphasised. It had been very much borne in upon him during the last few days that even with the latest and best of up-to-date machines they did not necessarily achieve an air service. An air service was dependent, quite apart from equipment, on the ground organisation that dealt with it. If we were able to make machines that we could run at one-third, or one-fifth, or even one-fifteenth of the present-day cost, that would not make possible a flight to Paris in thick fog and low clouds, and it would not enable the pilot to know whether he could start now or in an hour's time unless the meteorological service was very good. It was the improvement of the adjuncts to an air service, quite apart from the machine itself, or the skill of the mechanics who looked after it, or the pilots who flew it, that would make development possible. If it were possible to fly present-day machines in all weathers strictly to scheduled time, and for them to return strictly to scheduled time, no matter what the weather was, costs would be very considerably reduced as well as charges to the public. He had looked with great interest at the formulæ in the paper and he did not know whether there was a solution to any of those equations that gave one the value of profits. It seemed to him that if they could determine that accurately by means of an equation it would be an excellent thing for mathematical treatment. As a distinguished mathematician had said, " What comes out of the mathematical

mill depends on what you put into it," but there were so many variables in arriving at a result by mathematical methods that it was necessary to study the component factors entering into it before they could arrive at a figure for the profits they were likely to get. He laid stress on the particular item of the ground organisation. He was very much interested to see, in the latter part of the paper, M. Breguet's visualisation of the very large aeroplane. The difficulty of structure weight had always seemed to him to be rather insuperable if they went beyond a certain size. In the four-engined machine made by his firm, which weighed 30,000lbs., it seemed that they were gradually approaching the point where materials had been used to the best possible advantage, and there seemed little possibility of improving the use of those materials and getting over the theoretical disadvantage that was attendant upon increased span. He did not know whether M. Breguet, with his great engineering skill, had thought of any method by which that disability might be overcome. Without a doubt, were it possible to obtain a scale effect with larger sized machines, by which they could fly with greater loadings per square foot and thus decrease the span, such an improvement might be possible. In that direction it was rather interesting to know that in nature some of the bigger birds which, he was assured by Dr. Hankin, flew at the same speed, carried a greater load per square foot, although their landing speed was the same. It would appear that nature had got over structural difficulties by introducing a scale effect. Whether it was possible to utilise that in a very much bigger way in the construction of large machines he did not know. Perhaps M. Breguet could say something about it. He again thanked M. Breguet for his interesting paper, and congratulated him on having read it in English.

Captain GOODMAN CROUCH congratulated M. Breguet on his very interesting and rather optimistic paper, and the Society on having the opportunity of listening to one of the earliest pioneer aviators of France, who was also one of her greatest engineers.

He recalled that he had had the honour of being associated with M. Breguet in aviation some 10 years ago, when he (M. Breguet) put into the air a type of aeroplane which was called a double monoplane, since it was so unlike the usual box kite form of biplane then known. People looked at this curious beast and asked what it was, since with biplane wings it had a fuselage and was almost entirely of metal construction. One had only to consider the machines of a few years later to realise that M. Breguet was a true prophet, for it would be remembered that he alone at that time was the designer working on those lines.

With regard to the air transport costs quoted by M. Breguet, the list of prices shown for running costs of an aerial line of 800 km. length included an item of Frs.6.50 for sinking fund out of a total of Frs.17.41. This, in his opinion, was a remarkably high percentage. It indicated that in the hypothetical case M. Breguet had taken he had chosen a machine presumably with a far shorter life than that of present-day aircraft, and he believed this item could be considerably reduced. This appeared to be borne out by the length of life assumed by M. Breguet when considering the advantages resulting from such improvements in engines and in mechanical parts, as could bring reduction in sinking fund and upkeep charges. Under this head M. Breguet had assumed the life of present-day machines to be 200 or 250 hours, and predicted the possibility of improving this to 1,000 hours.

Captain Crouch ventured to suggest that even during the war the life of 250 flying hours had been reached, and even surpassed by some of the heavy bombers, and the figure of a 1,000 hours was hardly a prophecy since a total of approximately 800 hours had already been reached by a machine on the London-Paris Service.

With regard to the advantages hoped for from the betterment of aerodynamic

qualities, M. Breguet's fineness coefficient indicated a figure for L/D of approximately 18½. This appeared to be optimistic, but he dare not say much in criticism of the point, since M. Breguet had already shown himself to be a true prophet. Recent aerodynamic tests on a model of a Woyevodski type had given a maximum L/D of about 12, and that, as far as he knew, was the highest figure yet reached for a complete model.

M. Breguet's remarks concerning future large machines were teeming with interest, but he felt that M. Breguet was extraordinarily optimistic in assuming that the increase in volume available for passengers would be so much greater than the increase in weight, power and cost.

Finally, he again thanked M. Breguet for the lecture, which from a technical point of view gave so much food for thought.

Mr. W. O. MANNING said he was sure everybody appreciated the honour M. Breguet had conferred upon them by reading his exceedingly interesting paper. Those who had followed aviation from the early days would remember the large series of aeroplanes known as the Breguet type, and the brilliant engineering design that invariably characterised them. He endorsed what Captain Goodman Crouch had said to the extent that, although he was not connected with commercial aviation, he certainly expected that the life of aeroplanes and engines to-day in commercial work was considerably longer than 250 hours. He was not an engine builder and could, perhaps, speak with less bias on that particular point, but he knew he could introduce M. Breguet to one or two English engine builders who could beat that performance. It would give them a great deal of pleasure when they remembered that in the early days of aviation practically the whole of English aviation was dependent upon French engines if they were able now to return the compliment. M. Breguet had done a very great service to aviation by pointing out the enormous importance of improvement in aerodynamical efficiency. One tried to improve the efficiency of the machines, but one did not appreciate, until it had been pointed out so clearly, what a very important matter aerodynamical efficiency was, not only in the saving of engine power, but in increasing the useful load and in cheapening the cost of the machine. With regard to M. Breguet's large machine, he was, of course, up against the dimensional law that the weight went up considerably faster than the area and that there is a definite limit of size for machines of present-day construction and design. But it by no means followed that the limit was the same for other types. It was possible that a very large monoplane, such as that referred to by the Lecturer, presumably with high-lift wings, and with the passengers, fuel, engines, etc., distributed along the wings, might be capable of being constructed for a reasonable weight. He again thanked M. Breguet for his interesting paper.

Colonel W. D. BEATTY joined with previous speakers in congratulating M. Breguet upon having read his paper in English. There was one point which had struck him, and that was in regard to the symbols used. The efficiency factor he had assumed corresponded to our English L/D. Although there were exceptional cases where the technical experts in the two countries did speak each other's languages, the majority did not, but it was obviously desirable that they should all think in the same mathematical language. With regard to that he was glad to say that preliminary steps had already been taken, in conjunction with the French Air Ministry, in order to get down to the same basis in England and France. While he did not wish to plunge into the argument as to the possibility or otherwise of the very large machine, he felt rather glad that there seemed to be such hope for the future. We still had a lot to do in the way of building up the traffic necessary to make it commercially practicable.

Mr. O. T. GNOSSPELIUS, after expressing his interest in the Paper, congratulated M. Breguet upon his courage in assuming that what we called L/D, or efficiency of the machine, could be improved, because he was quite sure, by his own

experiments, that it could be done. They knew that certain experiments had been done at the N.P.L. and other places, and they got certain results, but if one made experiments one's self one got quite a different outlook. He was sure M. Breguet was quite right in saying he could get something like 15 to 1 L/D, because he himself had made pieces of wood in the shape of bodies, wings and tails which gave that effect, so that he did not see why the complete machine should not do the same. The trouble was that we did not know much about aerodynamics, and did not know the proper shape to make. It seemed to him that work on that line was very essential, because 15lbs. per h.p. was not practicable; we wanted to turn it into 30. In present machines the figure was more or less 15lbs., and he was very glad that M. Breguet had brought forward this sort of figure for efficiency.

Mr. A. P. THURSTON said that the lecture impressed one very much indeed, that famous men, like science, were international. We (in England) more or less regarded M. Breguet as one of ourselves, and felt it a very great honour to receive a lecture from him. He was a pioneer of many things, but it was not realised that over 1,000 of M. Breguet's all-metal machines were actually used in the fighting line during the war. That was a very considerable achievement.

M. Breguet had brought out very clearly that to increase the efficiency of a machine it was necessary to reduce the "useless surface" (surface invisible) to the minimum amount, and the ingenuity of our designers must be utilised in taking off all extraneous corners and everything which caused waste by increasing that surface. But there was a point which was not, perhaps, brought out quite so clearly, and that was that the efficiency in carrying weight per distance could be increased by actually increasing the speed of the machine and decreasing the lifting area. The great difficulty in this connection was that of landing speed. But there were ways of doing it which would enable them to get a higher speed still in the air with smaller surface, and yet maintain slow landing speeds. In other words, it was possible, as suggested by Mr. Handley Page, to get something of a scale effect by taking advantage—he was not at liberty to say how—of certain properties of the air. He did think that it would be possible to increase the present efficiency of our machines in order to get a greater weight mileage for a certain expenditure either of money or of fuel, and in that way increase the possibilities of commercial aviation. He had once taken the trouble to go through the figures, taking a line to India. Assuming there were a large number of machines, taking the cost of maintenance of grounds, and petrol at 2s. per gallon, assuming the organisation was so perfect that each machine could be flown for 10 hours a day, and each machine would last on an average two years, on that basis he had made out that it was quite possible to maintain a good dividend and charge passengers at the rate of 3d. per mile.

With regard to M. Breguet's remarks about engines, he would like to endorse what was said by Mr. Manning. It was only a few days ago, at Croydon, that a Napier Lion was pointed out which had been running continuously for 450 hours without being taken down. It was possible for British engines to do better still, and attain running efficiencies which would be considerably better than the 220 hours of the French engines.

He also endorsed M. Breguet's remarks as to aviation being the greatest future means of international communication, and in conclusion took the opportunity to thank M. Breguet for the courtesy which he had extended to him (the speaker) when he went through his works.

The CHAIRMAN translated some of M. Breguet's remarks, in which he explained that he was once of Mr. Handley Page's opinion that six tons was the limit at which the weight grew so fast that the area could not be expected to bear it profitably. He had proposed a complete departure in the type of construction, which, although it had not yet actually been put into being, he thought would

get rid of the difficulty of the relation of weight to wing surface. He did not claim as an invention at all, but he had made calculations by which, using the thick wing type of machine, burying the engine and load in the wings, and distributing them carefully along the wings, on a 50-ton machine, he hoped to be able to arrive at much the same wing loading and power loading as would be obtained on a smaller craft of 2 or 3 tons. The wings would be 7ft. thick.

A hearty vote of thanks to M. Breguet concluded the proceedings.

NOTES ON M. BREGUET'S PAPER.

Contributed by Captain W. H. SAYERS: I think it is most important and most encouraging to hear so very high an authority as M. Breguet expressing the opinion that very great improvements in the aerodynamic qualities of the aeroplane are not merely desirable, but are also possible. The data given in his Paper are conclusive proof—if proof be needed—of the value of any great improvement in the " fineness "—or in usual English terms—the L/D ratio of aeroplanes.

The figures as to costs, etc., given in the Paper relate to French practice and are not directly applicable to British conditions. In certain respects I think British aircraft constructors may rightly claim that they can improve on those figures both aerodynamically and in the equally important matters of the durability and longevity of their aircraft. Such criticisms do not substantially affect the justice of the author's general conclusions, with which I am in entire agreement.

I think, however, that the time has now come to question what have hitherto been regarded as the fundamental bases of aeroplane design—bases which are apparently accepted by M. Breguet for they are implied in his two equations Nos. 1 and 2.

The assumptions are that an aeroplane may be regarded as a heterogeneous assortment of surfaces and bodies, and that the forces on each of the component surfaces or bodies, taken separately, may be added up and will then represent the total of the forces on the aeroplane. Every aeroplane designer knows that these assumptions are in fact inaccurate. No isolated body of good form can be cut in two and have its resistance determined by summing the resistance or the forces on the parts.

That the resistance and lift of present aeroplanes can be determined with reasonable accuracy by this method is, I submit, evidence that present-day aircraft are aerodynamically merely a collection of unco-ordinated components. They will continue in this state for so long as designers allow themselves to be limited by a basis of design which is entirely empirical and seriously misleading. It is not true that a given wing has definite lift and drag coefficients at definite angles of attack which are independent of the body, tail and wing bracing structure to which the wing is attached. It is equally not true that the body, tail and other organs which form the complement to wings have force and resistance coefficients which are independent of the wing.

Because existing aeroplanes are so bad that they behave nearly as though these false assumptions were actually true, the designer comes to believe in them. Because he has come to believe in them, he has also come to believe that it is not possible very greatly to improve the aerodynamic efficiency of existing types of aircraft.

I am personally firmly convinced if designers can only be persuaded to forget all about the itemised resistances of the components with which they at present deal, and will regard a projected aeroplane as a single aerodynamic body, and will design it with an eye to its lines as a whole—just as they would design, say, an airship body—that it will very speedily be found possible to design a complete aeroplane having a L/D ratio of 20/1 or over, or—in M. Breguet's terms—with a " fineness " of .05 or less.

TRANSLATION OF LETTER FROM MONSIEUR LOUIS BREGUET, DATED 28th APRIL, 1922, TO THE ROYAL AERONAUTICAL SOCIETY.

Gentlemen,—I return herewith draft copy of the report of the meeting of the 6th instant, and regret that I have been unable, owing to absence, to reply earlier, as promised, to the various speakers who took part in the discussion. I very much appreciate their remarks, for which I thank them.

Replying in the first place to Mr. Handley Page, I agree with him that the Paper had in view only a part of the big problem of the future of aerial transport, but it is quite certain that while it is necessary to have good aircraft, it is equally indispensable to have as perfect a ground organisation as possible, otherwise the use of aircraft will be very uncertain, however perfect they themselves may be.

For instance, let us imagine modern navigation carried out as is actually the case with superb boats, but lacking any organisation of ports, routes, provision of buoys, lighthouses, wireless telegraphy, meteorological service, current charges, etc. The result would be practically negligible and its existence very precarious.

I did not raise this question at the meeting as I am of opinion that if from the present time until the fact is accomplished, sufficient funds are available, it is certain that excellent aerial ports, which are more easily and much more cheaply established than seaports, will rapidly come into being.

It is foreseen, however, that the aircraft destined to maintain the big international transport service will have to be of the amphibian type, and they will thus be able to utilise sea routes and have at their disposal the whole existing organisation in the big seaports throughout the world.

From carefully carried out experiments made in various laboratories I am able to state definitely that with the very good coefficients I quoted for "fineness" (indicating L/D efficiency), propeller efficiency, and minimum h.p. will certainly be realised in the near future.

I would like particularly to reply to Mr. Handley Page on the subject of large aircraft of the future. I can share his opinion that if aircraft are built on a larger scale whilst remaining geometrically similar, the ratio of wing structure weight to total weight will increase, since, all other things being equal, the weight of the wing structure, *i.e.*, spars, ribs, interplane struts, bracing, etc., increases as the surface to power $3/2$. For this reason I was for some time led to think that very large aircraft would not give results of interest, and that no comparison was possible between boats and aircraft, for even given an assured advantage to be gained by increasing the tonnage of ships, rather the opposite would obtain in increasing the size of aircraft. At the beginning of last year, however, I started to give serious thought to a type of monoplane with wings of a section deep enough to house engines, tanks and passengers. Further, by suitably distributing the loads on the wings it is easy to imagine an aircraft in which the dead weight, instead of increasing as the power $3/2$ of the area, will only increase directly proportional to the area, and under these circumstances there were no longer any disadvantages in increasing the size of the machines.

I sketched on the blackboard after the discussion how I envisaged such an aircraft. It would comprise three fuselages, one in the centre for the crew, controls, instruments, etc., while the other two on the right and left respectively of the first mentioned, and far enough apart, would be used as hulls or floats. These would contain first class cabins. Finally, the tanks and the float would be distributed inside the wings. This distribution in weights in large aircraft would obviously give them a considerable moment of inertia, but as there would be no need for "stunting," their large lateral moment of inertia would mean a high degree of stability in the air.

With big monoplanes the reduction of parasite resistance can be pushed as far as one likes, and it is to be hoped that results similar to those of plain wings furnished with the tail unit can eventually be reached. It follows that these large machines would eventually have characteristics comparable with those of large birds, and the coefficient which would be applicable to them in that case will certainly be better than those I quoted in the lecture.

To Captain Goodman Crouch I admit that certain British engines have a much longer life than 250 hours, but I ought to say that the average life of the engines used by French companies does not reach this figure.

I am entirely in agreement with Captain Goodman Crouch that in a few years aeroplanes will obtain an average life of 1,000 hours, and for this reason I have every hope of seeing engines reach 2,000 hours.

With regard to Mr. Thurston's remarks, may I say that actually there were more than 6,000 metal machines, and not 1,000, put into service during the war which are still being used.

Finally, I would like to confirm what was the basic point of my paper, *i.e.*, that technical research should be pushed forward without relaxation so that improvements already envisaged may be realised with as little delay as possible as well as those for which as yet one hardly dares to hope.

Yours, etc.,

(Signed) LOUIS BREGUET.

STRESSES IN AIRSCREWS DUE TO VARYING ENGINE TORQUE.

BY JOHN CASE, M.A., F.R.AË.S.

1. Since the driving torque exerted by the engine is a periodic function of the time, the speed of rotation must also be periodic, which implies that the airscrew must be subjected to inertia stresses as well as to the stresses due to air forces and centrifugal forces. In the case of engines having six or more cylinders these inertia stresses will not in general be important as the cyclic variations of torque will be comparatively small. But with engines having two or three cylinders these stresses must be considered, for it will readily be seen that the bending moment due to inertia forces is such as to increase the stresses due to the air load.

It will usually be found that the speed fluctuation is small, something of the order of three or four per cent., but these changes of velocity take place in such very small intervals of time that the angular accelerations are large, and the consequent inertia stresses may also be large, as much as 40 or 50 per cent. of the stresses caused by the airload. Thus, if a propeller for a two or three-cylinder engine be designed so that the resultant stress due to the air load and the centrifugal forces approaches the safe limit, the actual stresses may be large enough to cause rupture on account of inertia. Apart from the numerical value of the stresses we must bear in mind the fact that the material will be subjected to rapidly fluctuating stresses.

The problem is complicated by the fact that the resisting torque is a function of the speed, but we know from experience, and analysis shows, that the speed variation is very small. On this assumption we can find the maximum acceleration approximately from the formula

$$\frac{d\omega}{dt} = \frac{g\ (\text{max. driving torque} - \text{mean driving torque})}{\text{Moment of inertia of rotating parts}}$$

and this will usually be sufficiently accurate for practical purposes. In the analysis which follows we shall neglect the inertia of the connecting rods and reciprocating parts.

2. General Analysis.

Let I = the moment of inertia of the airscrew and shaft about its axis, lbs. ft.^{2}
$\omega = 2\pi n$ = the angular velocity in radians per sec.
V = the forward speed of the aeroplane, feet per sec.
T = the driving torque exerted by the engine, lbs. ft.
Q = the resisting torque exerted by the air, lbs. ft.

Now according to R. and M. 474, Q may be taken as

$$a - b\,(V/nP_m)^3$$

where a and b are constants, and P_m is the experimental mean pitch. For present purposes we shall take

$$Q = a - c/\omega^3$$

V being supposed constant, where

$$c = (2\pi V/P_m)^3\, b$$

If the driving torque is constant and equal to T_o, the steady speed ω_o is given by

$$T_o = a - c/\omega_o^3.$$

Now suppose that the torque becomes

$$T = T_0 + T_1$$

where T_1 is a function of the time, and suppose the consequent speed is

$$\omega = \omega_0 + \omega_1$$

where ω_1 is small compared with ω_0.

The equation of motion is

$$T_0 + T_1 = I\dot{\omega}_1/g + a - c/\omega^3$$

or

$$I\dot{\omega}_1/g - (c/\omega_0^3)(1 + \omega_1/\omega_0)^{-3} = T_1 + T_0 - a$$
$$= T_1 - c/\omega_0^3.$$

If we neglect powers of ω_1/ω_0 above the first, this gives

$$I\dot{\omega}_1/g + 3c\omega_1/\omega_0^4 = T_1$$

or

$$\dot{\omega}_1 + 3cg\omega_1/I\omega_0^4 = gT_1/I.$$

The solution of this is

$$\omega_1 = Ce^{-\lambda t} + (ge^{-\lambda t}/I)\int^t T_1 e^{\lambda t}\, dt$$

where

$$\lambda = 3cg/I\omega_0^4.$$

If we count time from when $\omega_1 = 0$,

$$C = -(g/I)\int^0 T_1 e^{\lambda t}\, dt$$

and

$$\omega_1 = ge^{-\lambda t}/I \int_0^t T_1 e^{\lambda t}\, dt$$

In general the integration can be performed graphically, or by expressing T_1 as a Fourier series.

The acceleration is given by

$$\dot{\omega}_1 = (g/I)\,[T_1 - \lambda e^{-\lambda t}\int_0^t T_1 e^{\lambda t}\, dt].$$

3. The Values of the Constants.

From R. and M. 474 we have

$$Q = \rho n^2 D^5 Q_c$$

where

$$K_q Q_c = 1.1042 - 0.833\,(V/nP_m)^3$$

and K_q is a number such that $K_q Q_c = 1$ when $V/nP_m = 0.5$. Thus,

$$Q = (\rho n^2 D^5/K_q)\,[1.1042 - 0.833\,(V/nP_m)^3].$$

Hence

$$a = 1.1042\,(\rho n^2 D^5/K_q)$$
$$b = 0.833\,(\rho n^2 D^5/K_q)$$
$$c = 0.833\,(2\pi V/P_m)^3\,(\rho n^2 D^5/K_q)$$

and, as above,

$$\lambda = 3cg/I\omega_0^4.$$

4. Approximate Calculations.

For two-blade propellers I is roughly $5\,wB_0^2D^3\,10^{-3}$ where w is the weight per cubic foot, and B_0 is the maximum blade width.

Also

$$e = \tfrac{1}{2}(V/nD)^3 (D/P_m)^3 (n^5D^5/K_q) \text{ approximately.}$$

Now V/nD and D/P_m are both of the order of unity, and K_q is of the order of 50, so that, roughly, C is of the order of $N^5D^5/100$.

Then

$$\lambda = (3g/16\pi^4n^4)(n^5D^5/100)(1000/5wB_o^2D^3) = (3g/800w)\, n\, (D/B_o)^2.$$

For most propellers D/B_o is about 10, and g is about equal to w, numerically, so that λ is of the order of $3\ n/8$.

As an example consider a three-cylinder engine, and suppose T_1 expressed as a Fourier series; the dominant term will be proportionate to $\sin 3\omega_o t/4$.

So let us take

$$T_1 = \tau \sin 3\omega_o t/4.$$

In this case it is easy to show that the maximum value of the acceleration is given by

$$\dot{\omega}_1 = (g\tau/I)\,[(3\omega_o/4)/\sqrt{\{\lambda^2 + (3\omega_o/4)^2\}}]$$

Now $(3\omega_o/4)^2 = 22n^2$ and we have already seen that λ is of the order $3n/8$. Thus we may expect the error arising from taking the approximate expression for the acceleration to be very small.

5. Bending Moment Due to Acceleration.

Let M denote the bending moment, due to inertia forces, on a section of the blade distance r_o from the axis of rotation. Then

$$M = \int_{r_c}^{R} r\dot{\omega}\,(r - r_o)\,dm$$

where dm is the mass of the blade element at radius r, and R is the extreme radius of the airscrew.

Let $A = aB_o^2$ = area of the cross section of the blade at radius r, where

B_o = the maximum blade width.

w = the weight of the material per cubic foot.

Then

$$M = (w/g)\ B_o^2\ddot{\omega}_1 \int_{r_o}^{R} ar\,(r - r_o)\,dr$$

and the integration is performed graphically.

The component of this about an axis parallel to the chord of the section is $M \sin\theta$, where θ is the pitch angle for the section under consideration. It is this component which must be taken in estimating the stresses.

6. **Example.**—Consider the case of a three-cylinder engine for which the torque is given approximately by

$$T = 400 - 750 \sin(3\omega_o t/4)$$

and $\omega_o = 180$ radians/sec.

$I = 22.5$ lbs. ft.^{2}.

$\lambda = 7$.

We find

$$\omega_1 = 0.0587\,(7 \sin 135t - 135 \cos 135t)$$
$$\dot{\omega}_1 = 7.927\,(7 \cos 135t + 135 \sin 135t)$$

and the maximum value is

$$(\dot{\omega}_1)_{max} = 7.95\sqrt{(7^2 + 135^2)} = 1072.$$

The approximate formula would give 1074 instead of 1072. Thus the maximum angular velocity range is only 7.95 radians per second, or about 4.3 per cent. and the maximum acceleration is 1070 radians per second per second. In the case under consideration this will cause an increase of compressive stress of about 40 per cent. at a section where $r/D = 0.2$.

ON RESEARCH AND OTHER MATTERS.

BY LIEUT.-COL. S. HECKSTALL SMITH, F.R.AË.S.

If the thought of another war troubles you, then don't read this article. If you would rather say to yourself as the Secretary of State said to the Air Conference, "There won't be another war for ten years, so why worry?" then no doubt you will think with him that it is better to let other nations have all the bother and expense of trying to advance; after all, we are jolly fine fellows and can soon pick up. If, on the other hand, you have imagination which gives you a nasty queasy sensation when you think of what might be, then perhaps the following notes, albeit disjointed and mostly stale, may at least conjure up in you thoughts of your own on the subject. This is all that is needed to help our advancement in the air—the stimulation of spoken and written thoughts by the British nation, for if every taxpayer in the British Empire says "Air Force," then the Press and Parliament will say it too.

In a terse letter to the "Times," our Chairman, Lieut.-Col. O'Gorman, C.B., pointed out the utter absurdity of the present position with regard to scientific research. I doubt with him that this is so much due to lack of money as it is to lack of imagination, for, as Colonel O'Gorman pointed out, it is not the *amount* of money which is being spent on the air, but the *percentage* which is being spent on research. It amounts to almost nothing. It has always been the same, and therefore there must be some reason for it.

I think, after many years of close contact with the problem, that the reason is this. The instigation and approval of research programmes are controlled by the wrong people. When I first came in touch with air research work we were controlled by the War Office—by soldiers. Now I am not going to say one word except in the highest admiration of the War Office and the Staff, but what I do suggest is that the better the War Office and the better the soldier (or sailor), the worse they are, *ipso facto*, for research. The great general is a man who fights with the weapons which are available, and uses them to the best advantage. If the fighter, no matter of what sort, said "I could beat this enemy if only I had thicker armour, longer range guns, poison gas, periscopes, paravanes, or what-not," then I say that such a fighter is no use.

It is not of such stuff that our Army and Navy are made.

On the other hand, it matters not one jot if the scientist who invented all these things should tremble at the knees at the sound of a gun!

The scientist need not be a fighter, able to do battle, in order to make war more terrible; all he need know is the broad principle of all wars, battles, or individual fights, which is to deliver a "decisive blow," and to have an analysis of the value of "blows," which are, I think, as follow:—

1. The weight.
2. The distance delivered.
3. The accuracy of aim.
4. The unexpectedness.
5. The speed of delivery.
6. Immunity of the deliverer.

The first pre-historic man who crouched behind a bush with a club, instead of using his fists in the open, used all the above points to his advantage. The man with the rock in a sling beat him because he improved on 2, 4, 5 and 6. The modern naval gun is better still on all points; and the aeroplane with bombs has again advanced.

The scientist can understand and appreciate these things, and give relative values to the items which are, of course, variable with the weapon used; thus with guns, weight of the blow with distance and accuracy are probably among the most important; whereas with poison gas, given the volume (or weight equivalent), the unexpectedness might be the greater value. It is entirely on the scientific advancement of the above points that the decisiveness of blows in future warfare will depend. It wasn't the well-known high excellence of the Scotch marine engineer that produced the marine turbine; and it is still less the high excellence of the British admiral that produced the submarine, which is merely an unfortunate outcome of the utilisation of electric energy discovered by scientific men. The soldier and the sailor have got to understand these horrid new weapons; they have, by use, got to develop and improve them and make them practical, with the help of engineers; but to devise them is to make practical men into dreamers, and a fighting man who dreams, well, he doesn't!

Now of all new developments there is none with such vast possibilities in war as aircraft. Compare them with any other blow-delivery weapons on the above six points! The weight of the blow?—there is no weapon which will deliver as much. Distance?—ten or fifteen times greater over land. Accuracy?—perhaps at present there may be some controversy as to this, but the possibility of development points to considerable accuracy. Unexpectedness?—nothing can compare. A hostile country could declare war with a bombing fleet, arriving over the enemy's country out of sight. The "three-dimension" movement of aircraft puts them far ahead on this most important point. Speed of delivery?—Again, over long distances on land or sea there is nothing to compare. Immunity?—Again I should say the advantage is with aircraft, landcraft coming next in order, and surface seacraft last, since they can be attacked from above, below and sideways, while offering a slower moving and larger target surface with less vision of the enemy or power to hide.

Another point might be added, and that is the cost of the blow in ton-miles. Here, I must confess, I have no data to work on, but it is an interesting speculation well worth arriving at. This much, however, one can cay. Suppose it was considered a decisive blow to drop 1,000 tons of explosives on a capital city, 300 miles away, 50 miles from the coast, and deliver the blow within 24 hours of starting operations. There is only one way to do so—by air. The Army plus the Navy could do it, but not in 24 hours; so the 4th and 5th points of the "blow" would be lost, and with the loss of these points the whole effectiveness of the "blow" would disappear.

The initial cost of the weapons by air for this would not be more than twelve millions, whereas the Army plus the Navy—even if they could do such an operation—would cost ten or twenty times that amount. Yet, one is told, we cannot afford an Air Force!

There can be only one possible reason for this, and that is that even now the value of research is not understood. One great difficulty about it being understood is that the non-scientifically-trained person cannot understand the working of the mind of the true scientific research worker. They talk a different language. To get a Government finance branch to put up money for a tangible thing which one can see and touch is hard enough, but to put up money for the intangible thing which a visionary scientist may suggest as a vague possibility without any promise of finality or value, if and when arrived at, seems to the finance branch an absurdity. This wretched scientist cannot even be relied on to stick to his original ideas. He may start on a non-ferrous alloy and end up by making a new explosive! Such a fellow is not to be financed. He may demand expensive apparatus, and when at the end of two years you ask him what he has done, he may show you some perfectly incomprehensible data on a dirty half-sheet of notepaper, or produce a few cheap-looking funny-shaped glass tubes with odd bits of metal and wire stuck on of no apparent value, and then turn

round and tell you " he is hopeful that he has accidentally hit on an interesting phenomenon."

So the financier shakes his head, vainly trying to understand it all. And yet, as a matter of course, he will use telegrams, telephones, wireless, or amuse himself with photography, kinemas, or take advantage of X-rays, electric trains, and will probably be the first to send his mails by air *when* they can be sent regularly, little thinking that none of these things would have been his for the asking but for the scientific, self-sacrificing researches of men of just this calibre! The man of science creates the wealth by extracting the secrets from nature and pointing out their use, the engineer develops them, and the commercial man takes the profits. The Press point out how they were the first to understand the whole thing, and the public, the politicians and the lawyers combine to dissipate the wealth as quickly as possible. Charles Kingsley wrote, many years ago, of what he called the " Aristocracy of Science." " What else," he says, speaking of this aristocracy, " what else, unless there be left in the nation, in society, as the salt of the land, to keep it from rotting, a sufficient number of wise men to form a true aristocracy, an aristocracy of sound and rational science? If they be strong enough (and they are growing stronger day by day over the civilised world), on them will the future of the world mainly depend. They will rule, and will act, cautiously, we may hope, and modestly, and charitably, because in learning true knowledge they will have learnt also their own ignorance, and the vastness and complexity and mystery of nature.

" But will they be able to rule? They will be able to act because they have taken the trouble to learn the facts and laws of nature. They will rule; and their rule, if true to themselves, will be one of health and wealth and peace, of prudence and of justice. For they alone will be able to wield for the benefit of man the brute forces of nature; because they alone will have stooped to conquer nature by obeying her."

The alternative to supporting the scientist was pointed out by Charles Kingsley. He goes on : " The aristocracy of mere ' order,' which means organised brute force and military despotism. And after that, what can come, save anarchy and decay and social death? " It is the scientist as Charles Kingsley saw him that we should support, for surely the sooner the world realises the foul terrors of future war, the sooner will wars end! It is in our half-developed state that peril lies; not even half-developed as far as the air is concerned. It is safer in the air to be a hawk than a sparrow. One cannot think yet the world is rid of hawks.

I find it is forgotten by the " man in the street " that on the outbreak of war in 1914 aircraft played no part in attack; in fact, it was not until the end of the war that we were in any sort of shape to bomb on a small scale with heavy bombs. As a real weapon to deliver decisive blows, aircraft did not exist in the war at all, therefore no deduction can be made from the war on this subject. What has to be decided is the minimum effective air force to deliver a blow with sufficient weight at a sufficient distance, with unexpectedness, secrecy and suddenness, with accuracy, and at a speed to make the blow decisive, at the same time making our air fleet as immune as possible.

Here is a field for research; almost every word of my " conditions " opens up a vast field of separate but closely co-ordinated work. The size and plan form of the aeroplane to take the most effective and economical form of bomb; the horse-power required, whether in one or more engines, will affect this, as will the petrol (or heavy oil?) consumption. The type of bombs, whether explosive or gas, or both; secrecy will depend on the height of flying, which involves the speedy development of super-charged engines and variable pitching of airscrews, together with research into metals, cooling, and fuel, all of which again tend to compromise the original plan or dimensions. The accuracy of aim covers

a very wide field, including the view of the observer, his ability to direct the aeroplane vertically over the object; the measurements of speed and height; the accuracy of aim when all these points are known, as well as navigation at great altitudes to the objectives. Further, the general weight and area of the "blow" depends on organised formations of the fleet. What a tremendous range of research we have here! High flying, with the engine difficulty and protection of the crew from cold and lack of oxygen; navigation through clouds in formation, which is essentially a matter of stability in the aircraft accompanied by accurate instruments—the compass, the turn indicator, the speed recorder, the height recorder, and the air mileage indicator, as well as wireless control of the formation of flights.

It must be understood that none of these instruments are perfect; all are possibly perfectable. But the use of them, the training with them, and the organisation are all wanting. The "unexpectedness"; this might at first seem a matter of pure military organisation of mobilisation stores, charts, equipment and skilled handling. It no doubt is, but is it not more? If we are to depend on a sudden attack, or counter-attack, at the very outset of the next war—as General Groves has so very clearly and ably pointed out we shall have to—then is it not a matter of military importance to see that our commercial air fleet will meet, to the best advantage, some of the points required to "deliver the blow"?

It does not follow that a good commercial aeroplane will make a good bomber; the conditions are utterly different. The commercial machine must first be economical, safe, and, if a passenger machine, comfortable. It has to "get off" every day, or several times a day, with full load, and still more important, land with full load; and there must be no undue risk. On the other hand, the bomber has to "get off" occasionally as a war risk with full load and land without it.

If, therefore, the commercial fleet is to be used in war—and everyone seems clear that it must—then it may be necessary to compromise the design of commercial machines, even at the expense of economy in transport, and loss of efficiency, to make these machines suitable for both purposes; such loss should therefore be made good by the Government in order to gain military advantage at the least expense in the long run. With these difficulties, the need for research and full-scale experiments will be obvious, the co-operation of all concerned essential.

The "speed of delivery"; this must depend on the size of the air force, its readiness, and the capabilities of its machines, personnel and staff. On the size because it is useless to deliver a swift blow without sufficient "weight," just as the weight is useless without the "aim" being good, and the value of the aim being modified if not "unexpected" so that the other fellow has time to dodge.

On the final question of the "immunity of the deliverer," it is difficult to predict as to whether the bombing fleet should be protected by other fighting machines or should rely on their own fighting qualities, or capabilities to dodge, or whether artificial clouds would protect them if made by themselves or other special accompanying machines. The Air Force, like the Navy, will no doubt learn all such tactics on manœuvres.

If commercial aircraft are to play any part in war, then the sooner it is decided what part or parts, the more likely they are to become effective and the more value to the nation will the Government subsidy for commercial aircraft possess.

At the present time there is a sort of apologetic feeling all round about subsidies, but I am sure this would disappear if the military value and postal value of commercial aircraft were made full use of; for then, and only then, will

the taxpayer appreciate that he is getting something for his money. To subsidise air lines to take American tourists to Paris or bring frocks made in Paris to London or cut flowers from Holland to sell in Covent Garden cannot be expected to appeal to the British public; but to deliver his mails to India, Australia, in double or quadruple quick time and thus increase the possibilities of overseas trade is within his understanding, as is also the value of defending his home.

Everyone pays for fire insurance, but most of us prefer also to pay for the fire brigade plus the water rate. And it is just because we are now without their equivalents in home defence that the public feel worried, or ought to.

The development of Royal Mail (Royal Air Force Reserve) Fleets is of the greatest importance to our safety. We want to see the Blue Ensign of the sea flying well above it, as well as on it. We are still a long way off making the Red Ensign a commercial success in the air, and it is just for this reason that I am offering these few notes on the whole subject. Not because I have anything new to say. It is not necessary to say anything new, or suggest any novelty, but only to repeat again and again the old expression of hope that research into such matters of national importance will be regarded as having importance, not impotence. For there is no doubt the power to create is available, the fertility of brains is never lacking; it is only the uniting of science and practice that is so difficult, that one would think they were things apart, never to be joined in wedlock, lest they should produce an offspring in the nature of a freak!

Yet, where have we got to in aircraft? An aeroplane is still a thing of wood and wire and linen and string. Had we the knowledge we might have (by research) on light alloys, I doubt not that the whole structure would change; in fact, if we knew the truth, we might find it had already changed—abroad.

If such a change as this came, it would alter the whole scheme of aircraft construction. The furniture-maker, piano-maker, joiner, carpenter and upholsterer would disappear, and the adequacy of the metal-worker to meet war demands would have to be considered, as well as the supply of raw materials, sheets and tubes, with the tools, jigs, fixtures and the like. It is clear that if aeroplanes had been all-metal when war came in 1914 we should have been in poor shape to meet the demand. It behoves us, therefore, not only to develop our fleets, but to consider their multiplication on a rapid basis in another war.

The air development will make our island a very different place in the next war. What about food supplies, supplies of raw materials? The merchant vessels will be an easy prey to hostile aircraft. What about the supply of oil and petrol even for our air fleets? I said these things made one feel queasy, but the shortage of food by the sinking of supply ships brings it home even more than an air raid by a "blow" of 1,000 tons of explosives (or poison gas) on London in 24 hours, delivered with "accuracy" and "unexpectedness." It seems almost worth while to spend a bit to counter this. I wonder if we shall? It is not so much, I expect, that we shall not spend as whether we shall spend in the right direction.

Quite probably the Army, Navy and Air Force have considered my six points of the "decisive blow" years ago, and we laymen don't know what they have got up their sleeves; all the same, there were a few times during the war between 1914 and 1918 when it took us all our time to cope with new things under heading No. 4, and then, and not until then, did the scientist come into his own. Personally, one would like to see him come in sooner; it's all right, we know, but these "jolly near shaves" affect the colour of one's beard. I'm all for calling in the doctor in good time, especially the doctor of science, in a matter which, without any shadow of doubt, is one of the most scientific that man has ever faced, and also the most important, as his life and future prosperity depend on lack of errors.

The ideals of true research are so obscure to the average non-technical man that the fact that there is no real research is frequently camouflaged by the flaunting of some interesting and important piece of experimentation which completely misleads the unwary into the belief that much is being done.

Experimentation is *not* research; it is a necessary adjunct to it, but should not be confused with either the work of research or the workers. A research into a new dye and an experiment in commercial dyeing require different types of brains and different education. Both are equally important; the second is not research, but may well affect the research, call on it, and help it. Thus, in looking into the amount which is actually being spent, the most important features to consider are: The ability of the Chief, by his past history, training and achievements, to Create, Control and Co-ordinate (three C's) true research; the Facilities given him, and the Freedom he has to select a competent staff, and the Financial resources he has to pay them (three F's).

Let the public satisfy themselves on these points and on the fact that such research will be followed by thorough experimentation, and this again by quantative practice; then, and not till then, will the "queasy" feeling subside, for the doctor of science will inspire in the patient public that confidence which will enable the public to say, "Every day and in every way we are getting safer and safer."

THE IMPORTANCE OF LOW WEIGHT PER B.H.P. AND LOW FUEL CONSUMPTION PER B.H.P. OF THE POWER PLANT FOR AEROPLANES.

BY A. L. ROWLEDGE.

The power plant of an aeroplane is usually designed by a different person situated in a different works from the aeroplane designer, yet it is essential that both should understand something of each other's work, if the best result is to be attained. It is of the first importance that the engine designer should have a clear idea of the value to the aeroplane designer attaching to low weight per b.h.p. and low fuel consumption per b.h.p., when considering a new design or comparing the merits of existing ones.

These notes are written entirely from the point of view of the engineer providing the power plant, and as a basis of discussion it is assumed that aeroplanes for various purposes of equally skilled design will have the same performance if the total flying weight per b.h.p. is the same.

We will divide up the weights of the machine as follows :—

W = Total flying weight.
A = Total weight of the aeroplane structure.
E = Total weight of the power plant (less fuel and tanks).
F = Total weight of the fuel and tanks.
L = Useful load.

It is intended that the engine weight shall include everything belonging to the engine, including engine supports and cowling, but not the fuel and tanks, which are taken as a separate item. The aeroplane structure represents everything belonging to the aeroplane (not included in one of the other items) including crew.

We will use capital letters for the total quantities, and small letters for the quantities per b.h.p., and in addition we will let the letter "t" represent time in hours, and "k" represent the value of the structure weight as a fraction of the total flying weight. The fraction varies in value of course with different types of machine, but probably the adoption of a constant is justifiable for our purpose.

Then

$$W = A + E + F + L$$
$$L = wBHP - eBHP - aBHP - ftBHP$$
$$l = w - e - a - ft$$
$$= w - e - kw - ft$$
$$= (1 - k)\, w - e - ft.$$

$$\text{B.H.P. to carry 1lb. useful load} = \frac{1}{(1 - k)\, w - e - ft}$$

It would perhaps be interesting to take some values for the various quantities, and to plot curves showing possible differences in performance.

We will assume for our purpose that $k = .32$ and that $f = .65$.

Diagram Fig. 1 shows the b.h.p. per lb. of useful load required when the time of flight is four hours. Three lines are shown on this curve for machines having total flying weight per b.h.p. of 10, 15 and 20lbs. respectively. The dotted curves show the result of a saving of .1lb. per b.h.p. on fuel consumption.

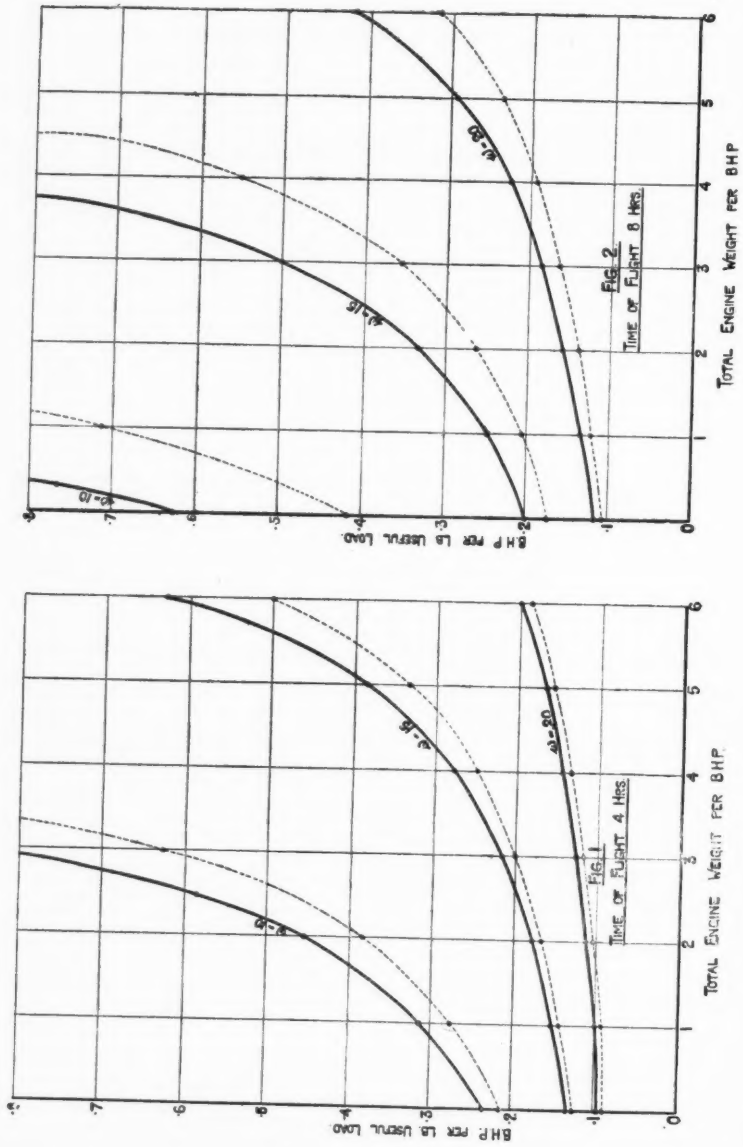
FIG. 1
TIME OF FLIGHT 4 HRS.
TOTAL ENGINE WEIGHT PER B.H.P.
B.H.P. PER LB. USEFUL LOAD.
FIG. 2
TIME OF FLIGHT 8 HRS.
TOTAL ENGINE WEIGHT PER B.H.P.
B.H.P. PER LB. USEFUL LOAD.

Diagram Fig. 2 assumes the same conditions except that the time of flight is now eight hours.

The load of petrol carried is taken on normal engine b.h.p. As the machine must be capable of carrying sufficient fuel for bad weather conditions it is thought that this is a satisfactory basis.

It is obvious at once from these curves that the importance of saving in weight per b.h.p. either in the engine or by fuel consumption varies very much with the type of machine. Commercial machines appear to be satisfactory with a flying weight of approximately 15lbs. per b.h.p., and apparently this figure cannot be very much exceeded owing to the necessity for a good take off. With long-distance bombing machines greater risks are taken. The curves show very clearly the impossibility of building a machine with high performance and a heavy engine. The usual weight of the power plant in commercial machines to-day (less fuel and tanks) varies between 3 and 5lbs. per b.h.p.

If we assume a machine is to be built to carry 1,000lbs. useful load, that it is a commercial machine, and that the desired performance is represented by a total flying weight of 15lbs. per b.h.p., then if the power plant weighs 3lbs. per b.h.p. and the desired maximum duration of flight is to be four hours, an engine of 218 b.h.p. will be required, and the weight of the aeroplane structure will be 1,046lbs. If the power plant weighs 5lbs. per b.h.p. the b.h.p. required will increase to 374 and the weight of the aeroplane structure to 1,795lbs. It is unnecessary to point out how the loss in efficiency will increase both the first cost and running costs.

CORRESPONDENCE.

To the Editor of the AËRONAUTICAL JOURNAL.

Dayton, Ohio,
June 22nd, 1922.

DEAR SIR,—In Colonel Ogilvie's Wilbur Wright Lecture, he expresses regret that the scientific laboratory work of the Wright Brothers back in 1902 and 1903 had not been published.

During my recent visit to Dayton I have had the opportunity of referring to the correspondence of the Wright Brothers at this period and it will, no doubt, be interesting to members of the Society to know that although the tables of the scientific laboratory experiments were not published, they were freely given at that time to several people who were interested in attempts to achieve mechanical flight. Mr. Chanute and Dr. Spratt had both full tables given to them in 1902 and 1903. Professor Marvin, now Chief of the United States Weather Bureau, and Dr. Zahm also received some of the tables at this time. Probably the fact that there were very few persons who were known to be interested in flight at that time, accounts for the comparatively small number of people who received these tables. It was only after the Wright Brothers had spent some thousands of pounds on their experiments, and it became necessary for them to recover this amount out of the invention, that further particulars of the invention were withheld pending negotiations for placing the machine on the market, and obtaining a modest reward for the risk and the work which they had successfully completed.

Very truly yours,
(Signed) GRIFFITH BREWER.

REVIEW.

14,000 Miles Through the Air. Sir Ross Smith.

This little book will make its appeal to thoughtful people, in that its story, ostensibly one of heroic enterprise, is brimming with promise of the future. Sir Ross Smith, in the space of 136 pages, gives us his "Pilgrim's Progress." How in just less than 28 days he flew half round the world; how he and his gallant crew climbed the Hill Difficulty; how across mountain and swamp, ocean and desert, through snow blizzard, through intense heat, he flew triumphantly home, cannot fail to quicken the imagination. The book is well illustrated with photographs, with the exception that it is a little difficult to see the relation of one or two of them to the text. The narrative is warm, well sustained, and not without a native humour; here and there by lack of a literary sense Sir Ross comes dangerously near to pathos, but his obvious sincerity compels the reader to forgive him, for he is a man of action rather than of letters. To the procrastinator his book is indeed a lesson. Again and again he pushed on under terrible conditions, after events proving that had he waited, fast flooding aerodromes would have held him prisoner. No less is it a beacon to all who set out on great quests. The minute preparations beforehand, the simple unison between man and machine without which neither can rise to perfection, the attainment of the physical fitness of both, were all implicit in the supreme moment of landing in Australia.

Perhaps it is those who make it their profession to fly that his story will touch most nearly. Yet what Sir Ross Smith, his brother and his two sergeant mechanics performed on an almost uncharted airway as a feat of endurance, will one day be a commonplace. Romance will become cold fact. Mankind will be apt to forget what it cost these pioneers of the air, who first linked up the Empire. In comfortable, swift, stable air liners, provided with adequate means of navigation and with wireless, they will scarcely remember the pioneer pilots, who were chilled and lonely, deafened with unsilenced engines, who ceaselessly reiterated the nervous routine of glancing from instrument to instrument in momentary fear lest a flickering pointer should convey the dread message that something vital had gone amiss. And Sir Ross Smith faced that ordeal, so he tells us, hour after hour, when flying over country that would yield not one friendly spot to land on for hundreds of miles. How natural the warm glow of human companionship and cheery welcomes where he paused en route! Even then he and his crew did not relax. Invitations to enjoy themselves were showered on them, much to their embarrassment; yet always they saw to their beloved engines, insisted on manhandling every pint of petrol into their tanks so that no dirt should enter, sacrificed their short sleep to hold the Vimy down when storms raged through the night, set out again if it were possible with the first light. From beginning to end it was a race against time; in spite of all that human forethought could devise it still remained a colossal hazard. They won, because sheer grit deserved them to win.

And now in his strong and vigorous youth the author has met with an untimely end. He died at the helm of his aeroplane, with his hands upon the controls. Can there be any doubt that his spirit rests

> "Among the chosen few,
> Among the very brave, the very true?"